Algorithm Acceleration for Geospatial Analysis
Geospatial Data

Google maps is a combination of vector and raster geospatial data, merged into a multi-layer visualization.
Geospatial Data: Vector

Vector data consists of points, lines and polygons with associated geographic coordinates and descriptive attributes.
Geospatial Data: Raster

Raster data consists of image layers comprised of pixels with associated geographic coordinates and descriptive attributes.
**Hyperspectral**
Remote sensing imagery comprised of multiple layers representing discrete portions of the electromagnetic spectrum.

(Hyperspectral Data “Cube”)

(x, y) = geospatial
\[ \lambda = \text{wavelength} \]

(Coral Reflectance Spectrum)

Reflectance

Wavelength (nm)

GTC 2012, San Jose, CA

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Project Motivation
Coral reef health is being threatened worldwide. Conservation requires effective quantitative tools for monitoring and assessment over large areas.

Healthy coral reef (left) – Dead (right)

Source: NOAA Photo Library; D. Burdick
Marine Remote Sensing

Detecting and identifying objects and surfaces through the atmosphere and water column is a complex process

Schematic of light interactions for coastal remote sensing

Source: Introduction to Subsurface Sensing; B. Saleh
Sunglint Correction

Specular reflection of sunlight from the water surface obscures underlying features and needs to be suppressed.

French Frigate Shoals, Hawaii – AVIRIS imagery
Understanding the Overhead
Without sufficient utilization of GPU resources, the benefits of GPU acceleration can be offset by input/output overhead.

Sunglint Processing Times
(200MB image; 1,305,600 pixels; 42 bands)

<table>
<thead>
<tr>
<th>Language</th>
<th>Time/_pixel (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDL</td>
<td>0.002</td>
</tr>
<tr>
<td>OpenCL</td>
<td>0.003</td>
</tr>
<tr>
<td>CUDA</td>
<td>0.001</td>
</tr>
<tr>
<td>C++</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Serial C++ sunglint correction algorithm outperforms GPU.

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Coastal Algorithm Overview
Applies to shallow coastal environments, e.g., coral reefs, deriving environmental information from hyperspectral imagery.

- Hyperspectral Imagery
- Inversion Model
- Water Properties
  - Water Depth
  - Bottom Albedo
- Unmixing Model
- Habitat Characteristics

Inversion model based on a constrained non-linear optimization.
Coastal Algorithm Overview

Using IDL, the native environment for ENVI (geospatial software), the algorithm takes ~60 minutes to process this small area (~500,000 pixels).
Optimization

Mathematical optimization routines are used to maximize or minimize a function to find the optimal solution.

1-Dimensional Optimization:
find 1-D global minimum or maximum

Source: www.mathworks.com; S. Kozola

2-Dimensional Optimization:
find 2-D global minimum or maximum

Source: mathworld.wolfram.com; J. Pinter

Optimization is used across an array of computing fields.
Understanding the Scope of the Problem

A naïve approach to solving the optimization problem using a brute-force exhaustive search was neither accurate nor efficient.
Understanding your Tradeoffs

In many complex problems there is often a tradeoff between speed and accuracy, and it is important to know the risk tolerance of the problem.
Introduction | Sunglint Algorithm | Optimization Algorithm | Real-Time Processing | App Development

Real-Time Processing?
With current optimization algorithm and utilization of GPU resources, performance is approaching real-time processing rates

Further improvements are needed to achieve real-time processing
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